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# An Analysis of 32 Surgically Managed Penetrating Carotid Artery Injuries

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*A review of the surgical management of penetrating carotid artery injuries in the Trauma Unit at Groote Schuur Hospital, Cape Town, is presented.*
***Materials and Methods**: a retrospective analysis of all surgically treated penetrating carotid artery injuries over a 3-year period was performed. The policy is to repair all injuries to the common and internal carotid arteries. Ligation is reserved for patients with prolonged coma; ischaemic infarcts or cerebral oedema on computerised axial tomography of the brain; technically inaccessible high internal carotid artery injuries, and those with occluded arteries with no distal patency detected during surgery or with angiography.*
***Results**: thirty-two patients with penetrating carotid artery injuries were reviewed. Eleven patients underwent emergency exploration. Twenty-one patients had angiography prior to exploration. Injuries in the emergency group were all repaired, with improvement in level of consciousness; also, two patients had preoperative neurological deficits that improved. Three of the 21 patients in the urgent group underwent ligation of the common carotid artery: one comatose patient with a hemiparesis died following ligation; the other two had improvement in their level of consciousness, one of whom showed improvement of his hemiparesis. The remaining injuries to the common and internal carotid arteries were repaired with improvement in level of consciousness and neurological deficit when present.*
***Conclusion**: operative repair offers the best chance of recovery.*

*Key Words: Penetrating injuries; Carotid artery.*

## Introduction

The general trauma surgeon is occasionally faced with the difficult and controversial decision whether to repair or ligate injuries to the common and internal carotid arteries (CCA, ICA) in the presence of coma and/or central neurological deficit. This report reviews a recent 3 year experience with 32 penetrating carotid artery injuries and focuses on the surgical management of the injuries and the neurological outcome of these patients.

## Patients and Methods

The records of all patients admitted to the Trauma Unit at Groote Schuur Hospital between January 1998 and December 2000 who underwent surgery for a penetrating carotid artery injury were reviewed. All unstable patients were resuscitated along Advanced Trauma Life Support® guidelines. Patients with active uncontrolled bleeding and/or haemodynamc instability with little or no response to resuscitation were taken to surgery immediately. Stable patients as well as those who stabilised after simple resuscitation and had evidence of a vascular injury (bruit, large haematoma), "proximity" lesions and transcervical gunshot wounds underwent routine aortic arch and four-vessel neck angiography. The Glasgow Coma Score (GCS), pre-operative systolic blood pressure (SBP) and gross focal neurological signs of central origin of each patient were recorded prior to surgical intervention. Computerised axial tomography (CAT) scan of the brain was performed in stable patients who had been in coma for more than four hours duration and/or who had focal neurological signs. Injuries to the CCA and ICA detected at emergency exploration were repaired – even in the presence of coma and/or central neurological deficit. Similarly, injuries to the CCA and ICA discovered with angiography without the disruption of distal flow were repaired. Ligation was reserved for patients with established ischaemic infarct or severe cerebral oedema on computerised

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tomography of the brain; where there was occlusion of the common or internal carotid artery with no distal patency at surgery or angiography, and in patients with prolonged coma of more than 4–6 h duration. Injuries to the external carotid artery (ECA) and its branches or to the internal jugular vein (IJV) that were encountered at surgery were treated by ligation. The patients undergoing emergency surgery and those undergoing urgent exploration based on angiography findings were analysed separately.

## Results

During this period we identified 32 patients who underwent surgery for a penetrating carotid injury. There were 29 males and 3 females with an average age of 27 years. Stab wounds accounted for nineteen of the injuries and the remaining thirteen injuries were the result of low-velocity gunshot wounds. Eleven emergency explorations were performed while twenty-one patients underwent angiography followed by urgent explorations. The distribution of injury in the different zones of the neck in the two groups is shown in Table 1.

### *Analysis of the eleven patients undergoing emergency surgery*

A total of 19 vascular injuries were recorded in this group of eleven patients. Injuries to the CCA and ICA were all repaired. Table 2 summarises the vascular injuries and their management. There were two associated injuries: an injury to the parotid gland and another to the hypopharynx were repaired and drained. Table 3 summarises the level of consciousness (GCS), SBP, as well as focal neurological signs and outcome of these eleven patients. After initial simple resuscitation five patients were fully conscious; had a SBP greater than 90 mmHg and had no central neurological signs. The remaining six patients presented with an altered level of consciousness (GCS range 4–11); three had a SBP greater than 90 mmHg while three had a SBP less than 90 mmHg. Two patients presented with a pre-operative focal neurological deficit: one with a GCS of 11 and a SBP of $>90$ mmHg had a right upper limb monoplegia with a 2/5 power grade. Post-operatively this patient improved to a GCS of 15 and the power grade in his right arm improved to 4/5. Another with a GCS of 8, a SBP $<90$ mmHg and a right hemiparesis improved post-operatively to a GCS of 14; improvement of his right hemiparesis was recorded. This patient displayed an expressive aphasia and a CAT scan of the brain post-operatively revealed an infarct in the region of the middle cerebral artery territory. Apart from the patient with the expressive aphasia, all the patients improved to a GCS of 15. No new focal neurological symptoms developed in any of the patients and no deaths were recorded.

**Table 1. Zone of injury.**

| Zone | Emergency | Urgent | Total |
|---|---|---|---|
| 1 | 1 | 1 | 2 |
| 2 | 7 | 16 | 23 |
| 3 | 1 | 5 | 6 |
| Posterior triangle | 0 | 1 | 1 |

**Table 2. Surgical management.**

| Vessel | Primary repair | PTFE | RSVG | Vein patch | Ligation | Total |
|---|---|---|---|---|---|---|
| Emergency cases – 11 patients | | | | | | |
| CCA | 4 | 3 | | 1 | | 8 |
| ICA | 1 | 1 | | | | 2 |
| ECA | | | | | 4 | 4 |
| IJV | | | | | 5 | 5 |
| Urgent cases – 21 patients | | | | | | |
| CCA | 3 | 7 | 3 | 1 | 3 | 16 |
| ICA | 2 | | | | | 2 |
| ECA | | | | | 2 | 2 |
| IJV | | | | | 7 | 7 |

### *Analysis of the twenty-one patients undergoing urgent surgery*

Twenty-one patients proceeded to urgent/semi-elective exploration based on angiographic findings. Angiography detected eighteen injuries to the common carotid artery and two to the internal carotid artery. Table 4 summarises the findings of these twenty-one angiographic investigations.

The angiogram reported as a "contusion" to the CCA was reported as such, because, despite no interruption of flow in the vessel; it was noted that the bullet moved with each carotid pulsation during angiographic screening (Fig. 1). The bullet was electively removed for fear of erosion into the carotid vessel and the development of delayed neurological symptoms. At exploration the bullet was found lying against the CCA, just proximal to the bifurcation. A duplex Doppler a week later showed an intact vessel with normal flow. The injury to the ECA revealed a false aneurysm of the lingual artery amenable to angiographic embolisation. This patient, however, just prior to an attempt to angiographically embolise

**Table 3 Neurological status of patients.**

| Pre-op GCS | SBP (mmHg) | Focal neurology | | Post-op GCS | Outcome A = alive |
|---|---|---|---|---|---|
| | | Pre-op | Post-op | | |
| ***Emergency Group – 11 patients*** | | | | | |
| Five patients | | | | | |
| 15 | >90 | Nil | Nil | 15 | A |
| Six patients | | | | | |
| 5 | >90 | Nil | Nil | 15 | A |
| 6 | >90 | Nil | Nil | 15 | A |
| 11 | >90 | R upper monoplegia | Improvement Power 4/5 | 15 | A |
| 4 | <90 | Nil | Nil | 15 | A |
| 8 | <90 | R hemiparesis (arm>leg) | Improvement (walk with crutch) | 14 | A |
| Post-op CT – MCA infarct | | | | | |
| 10 | <90 | Nil | Nil | 15 | A |
| ***Urgent Group – 21 patients*** | | | | | |
| 12 patients | | | | | |
| 15 | >90 | Nil | Nil | 15 | A |
| Five patients | | | | | |
| <15 (range 7–12) | >90 | Nil | Nil | 15 | 1 death |
| Three patients – ligation of CCA | | | | | |
| (i) 15 | >90 | L hemiparesis | Improved | 15 | A |
| *Pre-op CT – MCA infarct* | | | | | |
| (ii) 8 | >90 | Nil | Nil | 15 | A |
| *Angiogram – no distal flow CCA#* | | | | | |
| (iii) 5 | >90 | L hemiparesis | Coma | 3 | dead |
| One patient | | | | | |
| 12 | >90 | L hemiparesis | Improved | 15 | A |
| *Pre-op CT head: normal CCA repaired* | | | | | |

# See Figure 2.z

**Table 4. Angiography results of 21 urgent cases.**

| | Common carotid | Internal carotid | External carotid | Vertebral |
|---|---|---|---|---|
| Intimal flap | 1 | | | |
| Contusion | 1 | | | |
| Occlusion/transection | 2 | | | 1 |
| Extravasation | 11 | 1 | 1† | 1 |
| AV-fistula* | 3 | 1 | | |

* Fistulous communications with internal jugular vein.
† False aneurysm of the lingual artery.

the aneurysm, started to bleed profusely from the floor of the mouth and a lacerated tongue, requiring emergency exploration to control the bleeding. The false aneurysm of the lingual artery was ligated via a separate cervical incision during the same procedure.

Tables 2 and 3 summarise the management of the various injuries encountered and the neurological status of the patients' undergoing urgent surgery respectively. Three patients in this group underwent ligation of the common carotid artery. One with a GCS of 15 and a mild left hemiparesis, with a pre-operative CAT scan of the brain showing an infarct in the middle cerebral artery territory. He remained well with an improvement of his left hemiparesis. Another with a GCS of 8 with no obvious focal neurological deficit, had an angiogram showing occlusion of the CCA with no distal patency (Fig. 2). He regained consciousness with no focal neurological fallout. The third patient that underwent ligation presented more than 12 h post injury with a GCS of 5 and a left hemiparesis. Angiography revealed extravasation of contrast of the CCA with distal flow. This patient died in the immediate post-operative period. Another patient with a GCS of 12 and a left hemiparesis with a normal pre-operative CAT scan of the brain, had an injury to the CCA that was repaired with improvement of his hemiparesis and GCS to 15. The ten associated injuries in this group are shown in Table 5. There were two deaths in this group. The one described earlier and another who sustained a gunshot injury to the cervical spinal cord with a complete C6 – level quadriplegia. He had an interposition PTFE graft inserted for a CCA injury. He died a week later from respiratory complications.

There were two deaths in this series with an overall mortality of 6.3%. Shunts were not used in any of the cases.

## Discussion

Numerous studies have confirmed the safety of selective exploration of penetrating neck injuries.[1–4] Our trauma unit successfully practises a policy of selective conservatism of such injuries. It is generally accepted

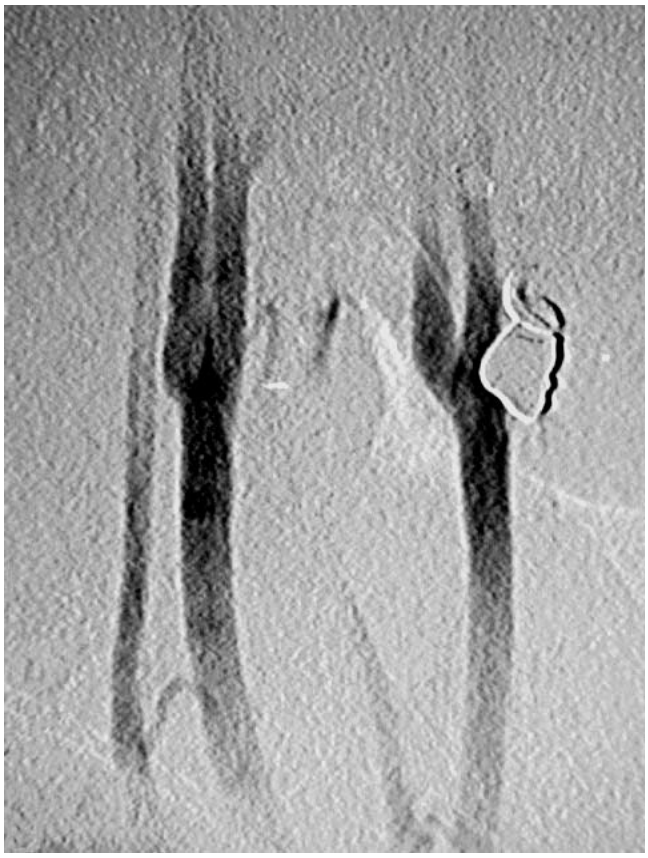

**Fig. 1.** Angiogram showing bullet abutting common carotid artery bifurcation.

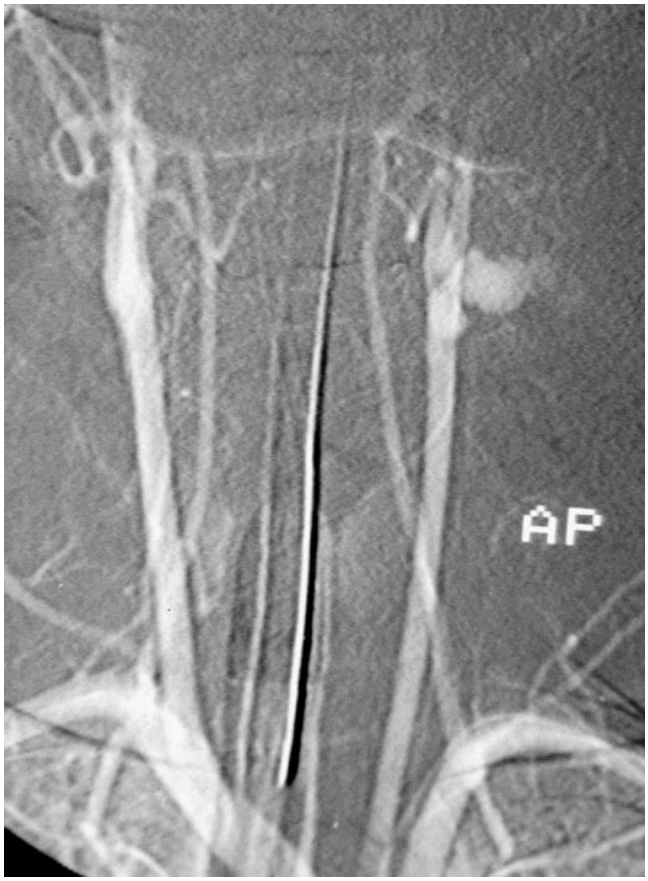


**Fig. 2.** Angiogram showing extravasation with occlusion of the left common carotid artery.

**Table 5. Associated injuries and their management in the urgent/semi-elective group.**

| Injury | | Treatment |
|---|---|---|
| Pharynx | 3 | Repair and drain |
| Mandible | 3 | Wiring |
| Vertebral artery | 1 | Ligation |
| Vertebral vein | 1 | Ligation |
| Trachea | 1 | Repair and tracheostomy |
| C6-paraplegia | 1 | Supportative |

that severe active bleeding, hypovolaemic shock not responding to resuscitation, rapidly expanding haematoma, a large blowing wound and major haemoptysis are indications for surgery. The remaining patients presenting with neck injuries are assessed clinically for evidence of an underlying visceral/vascular injury, and based on these clinical findings, appropriate ancillary/diagnostic investigations are requested. Table 6 summarises the clinical manifestations of underlying visceral/vascular injury in stable patients, and the investigations required to rule out an injury. In an audit of 116 patients with low-velocity gunshot wounds to the neck from this unit; there were 110 patients who presented in a stable condition. Eighty-nine patients (81%) underwent aortic arch angiography for a suspected vascular injury. Only 15 angiograms (17%) yielded a positive result; 14 patients underwent surgical exploration for a surgically-correctable lesion to the carotid vascular system and one patient had a coil embolisation of an external carotid artery false aneurysm. The authors concluded that initial conservative management of gunshot wounds to the neck is a safe policy in the majority of stable patients provided that selective angiography is employed, together with other diagnostic modalities to exclude visceral injuries.[5]

Injuries to the carotid artery occur in approximately 6% of penetrating neck trauma and account for 22% of all penetrating cervical vascular injuries.[6] The incidence of penetrating carotid artery injuries in our unit is 4.9%.[7] The treatment of penetrating carotid artery injuries has evolved over the past century. Ligation was the mainstay of treatment during the First and Second World Wars with a mortality rate of 40–47% and a cerebral complication rate of 30%. During the

**Table 6. Symptoms/signs associated with underlying visceral/vascular injuries.**

| Structure | Symptoms/signs | Investigation |
|---|---|---|
| Pharynx/oesophagus | Odynophagia | Gastrograffin swallow |
| | Dysphagia | +/− Endoscopy |
| | Saliva leak from wound | |
| | Blood in NGT | |
| | Haematemesis | |
| | Subcutaneous emphysema | |
| | Prevertebral air on lateral C-spine | |
| | Pneumomediastinum on CXR | |
| Larynx | Dysphonia/hoarseness | Laryngoscopy |
| Trachea/bronchus | Tension pneumothorax | Bronchoscopy |
| | Persistant air leak | |
| | Pneumomediastinum | |
| | Subcutaneous emphysema | |
| Vascular | External haemorrhage | Surgery |
| | Expanding haematoma | Surgery |
| | Pulsatile stable haematoma | Angiography |
| | Pulse deficit | Angiography |
| | Bruit | Angiography |
| | Widened medistinum on CXR | Angiography |
| | Transcervical gunshot | Angiography |
| | Shotgun wounds | Angiography |
| | Proximity gunshot | Angiography |

Vietnam and Korean conflicts arterial repair became routine and the morbidity dropped to 15%. Our mortality rate of 6.3% compares favourably with recently published series.[8–19]

Primary ateriorrhaphy, end-to-end anastomosis, vein patching and insertion of PTFE or reverse saphenous vein grafts are all acceptable means of repairing the injured carotid artery. Transposition of the external carotid to the injured internal carotid artery has also been described.[8]

All patients who do not have a preoperative focal neurologic deficit should have restoration of vascular continuity if technically feasible. This method of treatment is associated with good results in most series.[6,8–19] It also does not expose the patient to the risks of interruption of cerebral blood flow. For the patient with prograde flow with a false aneurysm, arteriovenous fistula or intimal flap, cerebral revascularisation can be accomplished fairly easily once vascular control has been achieved and the injury identified. If prograde flow through the carotid artery is shown to be absent either by preoperative arteriography or by operative exploration and the patient is neurologically intact the decision to restore vascular continuity will be based on technical considerations.[19] Arterial ligation (operative finding) or observation (angiographic finding) alone is the preferred treatment in this situation. However, the asymptomatic patient with occlusion of the CCA or ICA may result in late local or neurological complications. Arterial occlusion on angiography is often associated with transection and may lead to delayed false aneurysm formation and rupture. Propagation of thrombosis or emboli may result in delayed neurological symptoms. It would therefore be rational to ligate these injuries if technically possible.[6]

The most controversial issue continues to be the optimal management of the patient with a carotid injury and a central neurologic deficit. The adverse outcome following carotid endarterectomy for acute strokes has been extrapolated to the trauma patient with little attention given to the dissimilarity between the two groups. Wylie *et al*. described five autopsy findings of patients with acute strokes who underwent urgent thromboendarterectomy and revascularisation.[20] The findings showed haemorrhagic infarction of the brain in all five patients. Bradley described autopsy findings in two trauma patients with preoperative central deficits with haemorrhagic infarction as a cause of death following carotid artery repair.[21] These two reports and others[22,23] recommended against the re-establishment of carotid flow in the presence of preoperative neurologic deficit owing to the concern of converting an ischaemic infarct to a haemorrhagic one and worsening the neurologic status. A review by Liekweg and Greenfield in 1978 challenged this concept of postrevascularisation haemorrhage.[19] In their series of 223 patients with five deaths due to carotid injuries, cerebral oedema was reported to be the most common autopsy finding. Also, Demetriades *et al*. in a large autopsy series of 70 patients with repaired carotid artery injuries revealed only three patients with postrevascularisation haemorrhagic infarcts.[11] The most common

autopsy abnormality found was cerebral oedema. They suggested that oedema may predipose the brain to postrevascularisation haemorrhage because of softening of the brain tissue and recommended that repair should be avoided in patients with established ischaemic infarct or cerebral oedema seen on CAT scan of the brain.

The presence of coma has a poor prognosis, irrespective of the type of operative treatment.[6,8–19] In the emergency situation, a multitude of factors need be taken into consideration which maybe synergistically responsible for an altered level of consciousness. In the presence of shock, and/or injury to the carotid vessels, one cannot determine whether global ischaemia as a result of systemic hypotension or localised ischaemia as a result of the carotid injury is responsible for the altered level of consciousness. The extent of the effects of alcohol, illicit drugs and drugs administered as part of the resuscitation is also difficult to determine in the early period of presentation and resuscitation. Immediate revascularisation of patients in coma appears to offer the best chance of improvement.[6,8–19] The patient who is comatose and in profound shock should be treated with the objective that neurologic function will return to normal if bleeding is controlled, blood volume restored and the carotid artery injury promptly repaired.[17] However, most trauma surgeons would avoid revascularisation after more than 4–6 h of coma and in the abscence of backflow at operation.[6]

Certain arterial injuries such as small intimal defects, small pseudoaneurysms, minor dissection with intact distal flow; and high carotid-jugular fistulas can be treated with observation, endovascular stenting and/or arteriographic embolisation.[24]

The safety of modern shunts with carotid endarterectomy surgery is well established. However, the role of shunting in penetrating carotid trauma remains controversial. Some authors have found that shunting probably does not influence outcome.[11,16] Severe, complex carotid artery injuries requiring grafting or end-to-end anastomosis, especially in the presence of hypotension and pre-operative neurological deficit, may possibly benefit from shunting.[6]

This series, as with most others, retrospectively describes a small number of patients with penetrating injuries to the carotid vessels reaching the operating room alive. Our results are comparable to most series and the current literature supports our policy: carotid artery injuries should be repaired as soon as possible in the emergency setting. Angiography should be reserved for stable patients. A CAT scan of the brain should be performed in stable patients with delayed presentation with prolonged coma (4–6 h) and/or with central focal neurologic signs. Ligation should be reserved for technically difficult high internal carotid artery injures, established infarct/cerebral oedema seen on CAT scan of the brain, coma of more than 4–6 h duration, the absence of backflow at surgery and in neurologically intact patients with occlusion on angiography.

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